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Sustainability transitions in the agri-food sector: How ecology affects transition dynamics

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ABSTRACT

In this paper, we study sustainability transitions in agriculture and highlight several elements that distinguish transition dynamics in this sector from those more frequently studied in the socio-technical transitions literature. Our assumption is that ecological dimensions of agricultural systems affect transition dynamics. We illustrate this by focusing on two central characteristics related to biodiversity conservation: place-based embeddedness and the public goods' character of biodiversity. A qualitative, multiple-case study was conducted on the Dutch dairy sector by carrying out 22 in-depth interviews. We show how change in the agricultural sector is strongly geographically embedded and dependent on regime actors who need to be enabled and incentivized to partake in the transition process. Due to the public goods' character of biodiversity, there is a strong focus on the development of institutional novelty. Dynamics of change show a specific fit between ecological conditions and innovation.

1. Introduction

Biodiversity loss is one of the largest environmental problems of the 21 st century, and is taking place at unprecedented rates due to various human-induced effects on the global environment (Vitousek, 1994; Sala et al., 2000; Diaz et al., 2019). Agricultural production systems have profound negative effects on biodiversity through conversion and fragmentation of natural habitat related to agricultural expansion, and as a result of pollution due to the overutilization of inputs such as pesticides and fertilizers (Sala et al., 2000; Rockström et al., 2009; Scherr and McNeely, 2008). This calls for a radical transformation of how agricultural sectors produce commodities. For this transformation, farmers need to alter various practices such as providing foraging areas for wildlife and nesting locations on farm land, decreasing chemical inputs, avoiding water pollution, promoting biological activity in the soil and enhancing habitat connections and ecological networks in the landscape (Scherr and McNeely, 2008; Tscharntke et al., 2015; Prager, 2015). For these practices to flourish, major changes in agricultural supply chains, business models and government policy are needed.

Understanding transformations of agricultural systems to enhance biodiversity represents a societal transition problem to which existing transition models, such as the multi-level perspective (Geels, 2002), or the innovation system perspective (Hekkert et al., 2007; Bergek et al., 2008), may be applied. These perspectives offer useful lenses to study the dynamics of change and insights into how novelty becomes more compatible with established regimes, ultimately leading to regime shifts. Currently, the lens of the multi-level perspective is increasingly applied to the agricultural sector (Elzen et al., 2012; Wigboldus et al., 2016; Bilali et al., 2019).

However, there are also reasons to assume that existing transition models would not directly fit transitions to sustainable agricultural systems. Most critically, while the role of ecology is important in agricultural systems, the socio-technical transitions

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literature does not consider interactions with ecological aspects and thus lacks understanding of its implications for societal change (Ollivier et al., 2018; Patterson et al., 2017). Different literature fields specifically focus on challenges related to biodiversity loss (e.g. the fields of social-ecological systems and conservation biology). From these streams of literature, we derive two main characteristics of biodiversity relevant to the agricultural sector, which most probably have implications for our understanding of sustainability transitions in this sector: first is the place-based embeddedness of agricultural systems, which is a critical issue as it is in this place-based context where ecological, biophysical and geographical dependencies occur (Wigboldus et al., 2016; Pigford et al., 2018; Bilali et al., 2019). Second, in attempts to promote biodiversity in agriculture, specific problems arise due to the public goods' character of nature (Pascual and Perrings, 2007; Ostrom, 2009; Batáry et al., 2015). These aspects are expected to lead to different transition dynamics in comparison to socio-technical transitions where place-based embeddedness and public goods are less important.

To this end, we set out to broaden and enrich the existing transitions perspective by illustrating how these ecological aspects influence the dynamics of change in our study of sustainability transitions in agriculture. Dynamics of change are studied around the innovation of sustainable agricultural practices. We study cases of biodiversity conservation in the dairy sector in the Netherlands. The Dutch dairy sector is highly productive and is characterized by bulk export for the world market. It covers 60 % of agricultural land in the Netherlands (Van der Peet et al., 2018) and is known for its highly intensive agricultural practices (Bos et al., 2013). Different forms of agricultural intensification, such as inputs of chemical fertilizers, crop monocultures, drainage, early and frequent mowing methods, conversion of pastures into arable land and scale enlargement programs have had major consequences for biodiversity in Dutch meadow landscapes (Bos et al., 2013; Donald et al., 2001; Gregory et al., 2005). Strong declines of species populations, such as insects and meadow birds, have taken place over the last decades, including a decline in farmland birds of over 30 % between 1990 and 2017 (Donald et al., 2001; Gamero et al., 2017; Compendium voor de Leefomgeving, 2018). In response to this, several initiatives to curb these trends have emerged, including work on a transition toward a more nature-inclusive form of dairy production in the Netherlands. We studied the emergence of four of these initiatives in depth, by conducting 22 qualitative interviews with relevant stakeholders.

By addressing sustainability transitions in the agricultural sector, this paper contributes to the socio-technical transition literature by providing insights into the applicability of transition models to this sector, and into transition processes where nature and ecology play an important role. We address the current shortcomings of neglecting interactions with ecological factors, and illustrate how including notions of ecology affect the dynamics of sustainability transitions in the agricultural sector. Theoretical implications of these findings are discussed using the multi-level perspective. We pinpoint the characteristics of this sector and compare it with previously studied transition dynamics in the energy and mobility domains. Our findings contribute to a better understanding of sustainability transitions in agriculture, which can help to accelerate a much-needed transition.

2. Theoretical background

2.1. Sustainability transitions in agricultural sectors

Transition literature provides insights into various conditions and change processes that foster emergence and diffusion of novelty in socio-technical systems. Socio-technical (ST) transitions describe fundamental changes in the way societal functions – such as mobility, healthcare and food provision – are fulfilled by socio-technical systems (Geels et al., 2016; Markard, 2018). Socio-technical systems essentially have three main dimensions: actors, institutions, and technological and material artefacts. A transition requires deep changes in all of these system dimensions (Geels, 2004; Markard, 2011; Geels et al., 2016; Markard, 2018). A specific subset of ST transitions are sustainability transitions (Markard et al., 2012). These are long term, fundamental and purposive changes in STs with the aim to fulfil societal functions in a more sustainable manner (Markard et al., 2012).

Sustainability transition research tended to neglect transitions in the agri-food sectors (El Bilali, 2019). However, in the neighboring field of agricultural innovation, scholars have contributed to a better understanding of change within agricultural sectors. This field has matured into system approaches to analyze change, most notably, the agricultural innovation system perspective (AIS) (c.f. Klerkx et al., 2012). An AIS is defined as: "*A network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect the way different agents interact, share, access, exchange and use knowledge*" (Hall et al., 2006). Innovation in the agricultural sector captures technological, social, organizational, economic and institutional changes (Klerkx et al., 2012, World Bank, 2006). It balances new technical practices with alternative ways of organization of markets, land tenure, and distribution of benefits (Leeuwis, 2004). The AIS perspective is being increasingly linked to transition theories by studying how the functioning of agricultural systems is hampered, and how it might be supported. This has been done by applying the technological innovation system approach, and more recently also by incorporating literature on innovation ecosystems (Klerkx et al., 2012; Pigford et al., 2018). The AIS literature has paid particular attention to innovation within the industrial agriculture paradigm, but has not specifically considered ecological elements (Foran et al., 2014; Wigboldus et al., 2016; Pigford et al., 2018). Different scholars highlight the need to go beyond an analysis of AIS in order to better understand sustainability challenges within the agricultural sector (Wigboldus et al., 2016; Pigford et al., 2018).

Another perspective increasingly being applied to better understand change in the agricultural sector is the multi-level perspective (MLP) (Elzen et al., 2012; Wigboldus et al., 2016; Bilali et al., 2019). The MLP framework has been developed within the STS community to understand technology adoption and upscaling, mainly through studying dynamics of change in technology dominated sectors like the energy and mobility sectors in the Global North (Markard et al., 2012). The multi-level perspective describes and conceptualizes overall patterns of change within socio-technical transitions for three analytical levels: niche (micro), regime (meso) and landscape (macro). Transitions toward more sustainable socio-technical systems are difficult to achieve when incumbent systems

are characterized by a high level of institutionalization, or lock-in. Processes of lock-in are captured in the notion of socio-technical regime, or the 'deep structure' that provides stability to existing systems (Geels, 2004). This stability is mainly due to a set of formal and informal rules, such as regulations, cognitive structures and shared beliefs, and due to established practices, which are maintained and defended by incumbent actors (North, 1990; Rip and Kemp, 1998; Geels, 2002, 2005a; 2018). The regime can be pressured by the exogenous socio-technical landscape, which includes slow-changing societal values, demographic trends and macro-economic patterns (Geels, 2011).

Important findings from studies in the energy and mobility sectors are that emerging novelties often fail to compete within existing socio-technical regimes. New technologies often perform poorly and are too expensive to compete with regime products. Therefore, they need to be protected or shielded. Such a protective space is labelled a 'niche' (Kemp et al., 1998; Rip and Kemp, 1998). Typical shielding measures to protect niches are subsidies and other public or private measures that support them, such as subsidized demonstration projects or R&D laboratories (Coenen et al., 2010; Geels et al., 2017). Due to the shielding measures, actors that develop the innovations buy some time to improve the innovation to be capable of competing with existing technologies, services and products at a later stage (Geels and Raven, 2006). Different processes have been found to support the niche and facilitate breakthroughs, such as experimentation, network building, articulating positive expectations and mobilizing resources (Kemp et al., 1998; Raven, 2005; Hekkert et al., 2007). Learning processes are important to improve technological performance and to achieve cost reductions (Junginger et al., 2006).

Niche innovation can either fit-and-conform under current regime selection environments, through which regime conditions typically remain unchanged, or they can contribute to change in current regime environments, and thereby influence their selection environment through, for instance, institutionalizing niche practices into re-formed regimes (Smith and Raven, 2012). Different transition pathways are conceptualized in which transition dynamics are outlined based on various kinds of MLP-alignments (Geels and Schot, 2007; Geels et al., 2016). Transition studies have shown that new entrants often introduce novelty, and replace incumbent actors with their radical innovations: the technological substitution pathway (Geels et al., 2016). However, sometimes incumbent actors take the lead, either by incremental adjustments or more radical substitution of technologies. This is referred to as the regime transformation pathway. In the regime reconfiguration pathway collaborations between new entrants and incumbents lead to novel combinations between new and existing technologies. The de-alignment and re-alignment pathway describes how regimes are destabilized by rapid landscape pressures (Geels et al., 2016). With respect to incumbents, the focus in the transition literature traditionally lies on powerful and large actors, who are for instance able to buy up smaller firms in order to control innovation, or to force changes in sectoral trajectories (Kishna et al., 2017; Geels, 2019). The transition pathways typology has been found useful to explain why the character of transition dynamics differs between countries or domains (Geels, 2019).

Different critiques have been raised regarding the applicability of the MLP framework to understand sustainability transitions in the agricultural sector. Bilali et al. (2019) concluded that more work needs to be done to make the MLP 'fit-for-purpose' to study the agri-food sector, mostly regarding the analysis of transition dynamics and transition pathways to this sector (Bilali et al., 2019; Pigford et al., 2018). Current critical shortcomings include omitting geographical, biophysical and social-ecological elements in the analysis, while these are salient in the agricultural sector (Coenen et al., 2012; Hansen and Coenen, 2015; Wigboldus et al., 2016; Pigford et al., 2018; Bilali et al., 2019). In addition to scholars studying agricultural systems, the broader ST community also states that current socio-technical transition frameworks do not consider interactions with ecological aspects, and thus lack understanding of its implications for transition dynamics (Moore et al., 2014; Patterson et al., 2017; Ollivier et al., 2018).

This paper starts from the assumption that ecological dimensions of agricultural systems affect sustainability transitions in the agri-food sector. To address the shortcomings mentioned, the next sections aim to unpack how ecology, in our case biodiversity, is relevant to understand transitions in the agricultural sector.

2.2. Biodiversity conservation in agricultural landscapes: insights from different literature fields

Biodiversity loss is a key problem in agricultural landscapes[1] (Sala et al., 2000; Rockström et al., 2009; Scherr and McNeely, 2008). Challenges of resource competition, land degradation and pollution resulting in biodiversity loss are complex and are related to unsustainable human-environmental interactions. Different fields specifically focus on challenges related to biodiversity loss (e.g. fields of social-ecological systems and conservation biology). From these fields, we derive two key characteristics of agricultural systems that can improve our understanding of the ecological dimension of sustainability transitions: place-based embeddedness and the public goods' character of biodiversity.

(1) *Place-based embeddedness of agricultural systems: ecological, biophysical and geographical dependencies*

Agricultural systems are largely place-based and embedded in geographical areas. Ecological conditions are location-specific and vary geographically. This place-based character determines, to a large extent, the type of production system and commodities that can be produced, the type of habitat for biodiversity, and the specific ecological challenges that can be expected. Biodiversity conservation therefore brings specific challenges depending on the habitat conditions. Moreover, the maintenance of biodiversity also depends on processes and configurations in the wider landscape (Prager, 2015). For example, management on a landscape-scale can

[1] In this paper, we refer to "landscape" as the biophysical landscape in which agricultural production takes place, not the conceptual macro-level landscape of the MLP.

contribute to biodiversity conservation by creating ecological networks and reducing habitat fragmentation. This raises the importance of collaboration between different actors, for instance through cross-farm or cross-sectoral collaboration (Tscharntke et al., 2015; Reed et al., 2016). Sustainability strategies need to be tailored to specific habitat needs within the context and the history of the agricultural landscape (Blann, 2006; Scherr and McNeely, 2008). How actors address sustainability problems is context dependent as well. Histories of actors embedded in certain places determine to what extent actors are dependent on ecological resources for their livelihoods, or attach high value to the sustainability of the resources and are motivated to act. The conditions linked to sustainable outcomes are therefore often context-specific (Ostrom, 2009; Nagendra and Ostrom, 2014; Reed et al., 2016).

(2) *Public goods' character of nature conservation in agricultural sectors: need for incentive systems*

A main problem hindering conservation in agricultural landscapes is that a direct gain for actors to invest in biodiversity is often missing, which underlines the need for supporting institutions and governance, for instance via incentive mechanisms (Tilman et al., 2002; Pascual and Perrings, 2007; Batáry et al., 2015). At the heart of this problem lies the public goods' character of nature conservation. Already in 1968, Hardin described the social dilemmas that results from the governance of common pool resources (Hardin, 1968; Ostrom, 2009). In the social-ecological systems literature, this is referred to as the "provisioning dilemma", which occurs when costs of investments are individually paid, whereas the benefits are shared between actors. Moreover, benefits are often visible on a longer term, while the investments are required on the short-term. This is the case for many public goods, such as biodiversity, clean air or other ecosystem services (Garnder et al., 1990; Ansell et al., 2016). Markets and institutions often do not provide financial incentives for biodiversity conservation in agricultural landscapes; biodiversity conservation is for instance not valued in product prices. This lack of incentives is an important cause for farmers' decisions to not invest in agrobiodiversity (Pascual and Perrings (2007). As an example, financial investments are needed for providing natural areas for meadow birds on agricultural land. Moreover, besides local benefits, biodiversity conservation on agricultural lands often generates ecological benefits elsewhere (positive externalities), for which also often no incentives are provided. This results in the tendency of individual actors to minimize investments in biodiversity. A classic example regards the reluctance of upstream farmers to engage in pro-environmental behavior (e.g. regarding pesticide use, or refraining from forest clearances) that would mostly and most immediately benefit their downstream colleagues. There are usually no markets for these off-site ecosystem services (Pascual and Perrings, 2007).

These problems of underinvestment in biodiversity have led to extensive studies in the fields of social-ecological systems and conservation biology on how to overcome these dilemmas, for example by fostering collective agreements and developing incentive mechanisms (Ostrom, 2009; Guerrero and Wilson, 2017). Collective agreements revolve around deciding on how different actors collectively manage natural resources sustainably, by setting rules and standards. Incentive mechanisms are considered important to incentivize actors to invest in biodiversity. These can both be organized at different levels: at the local level collaborations between farmers can result in new collective agreements. Since decisions are also strongly influenced by the meso-economic environment (e.g. markets and national institutions), institutional changes need to occur at this level as well to overcome market and institutional failures. Incentives can be grouped into two categories: (i) regulation, planning and moral persuasion – for instance through prevention of specific land management practices through legislation and policies; and (ii) providing financial incentives in exchange for biodiversity conservation via market creation for biodiversity or through governmental incentive-based mechanisms, such as agro-environmental schemes (Pascual and Perrings, 2007; Batáry et al., 2015; Ansell et al., 2016).

2.3. Innovation in the context of biodiversity conservation

This paper departs from a socio-technical perspective to better understand transition dynamics in the agricultural sector. To study dynamics of change, we first need to clarify how we define technology in our case. Our definition of technology is inspired by Arthur (2009), who claims that technology encompasses both components (artifacts), and practices. Innovation can thus occur in both. In this paper, we define technology as: sustainable agricultural practices, revolving around biodiversity conservation. We expect that transition dynamics around this innovation are affected by two central elements of biodiversity conservation in agricultural systems, i.e. place-based embeddedness and the public goods' character of nature. We apply the MLP perspective as a socio-technical approach, as this has proven to be a useful lens to understand transition dynamics and pathways. Using this perspective, we study and discuss how novelty emerges, how niche-regime interaction takes place, and how niches potentially scale up.

3. Methods

3.1. Research design

We conducted a qualitative multiple-case study (Eisenhardt, 1989) in order to illustrate theoretical insights into transition dynamics in the agri-food sector. Through an MLP lens, we explore niche-regime dynamics by analyzing processes of the emergence of novelty; the upscaling potential of novelty, and the role of agency in niche emergence. We study the Dutch dairy sector, by analyzing four initiatives that aim for a shift toward biodiversity-friendly dairy production.

3.2. Case description

Promoting biodiversity in sustainable dairy production in the Netherlands links to the policy concept "nature-inclusive

agriculture", which was recently adopted by the Dutch government, and aims to stimulate more sustainable agricultural practices in dairy landscapes, thereby minimizing negative ecological impacts, and achieving positive ecological impacts such as conservation of biodiversity and ecosystem services (EZ, 2014; Runhaar, 2017a). The Netherlands is renowned for its highly efficient and productive dairy sector. The dairy sector is characterized by highly intensive farmer practices, which were steered by post-war policies toward maximization and production of homogenous bulk products for the world market. Almost two-thirds of all milk processed in the Netherlands is exported. Europe is the most important export region; within Europe, about 70 % is exported to Germany, Belgium and France (ZuivelNL, 2018). Farmers are highly dependent on the wider agri-food system (e.g. dairy advisers, banks, retailers and food manufacturers). Because of skewed power divisions between farmers and other actors in the value chain, farmers are usually 'price-takers' (Assefa et al., 2014). Their ability to single-handedly change practices is limited due to low margins, high land costs and investments in specialization (PBL, 2018; Runhaar, 2017a). This often results in strategies of cost-reduction or scale enlargement strategies by farmers (Röling, 2009; Assefa et al., 2014; PBL, 2018). Sixty percent of the Dutch agricultural area consists of meadow landscapes used for dairy production (Van der Peet et al., 2018). Agricultural intensification and farm scale enlargement have changed the Dutch agricultural landscape enormously, which resulted in grass monocultures (perennial ryegrass), which are managed through the use of chemical inputs and fertilizer (Runhaar, 2017a). This has led to severe biodiversity loss, habitat loss and degradation of ecosystem services, such as soil fertility and decreased water quality in the surrounding landscape (Brouwer et al., 2016; EEA, 2015a, 2015b). The most well-known example is the decline of meadow birds, such as the Black-tailed Godwit, in the Netherlands, which serves as a breeding ground for a large portion of the European population (Van der Vliet et al., 2015). Earlier efforts have not been able to curb this trend. Labels for organic dairy production already stimulate lowering the environmental impact by less intensive production and reducing (chemical) inputs, but do not necessarily focus on biodiversity conservation. Current government support via agri-environmental schemes (AES) does stimulate agricultural biodiversity conservation, however budgets are limited and these schemes only apply to designated "core" areas (77.351 ha in 2018, out of the approximately 1.7 million hectares of agricultural land) (Runhaar, 2017b; Boonstra and Nieuwenhuizen, 2019; CBS, 2019). Therefore, different actors call for a system transformation toward nature-inclusive agriculture. Various initiatives are emerging where different types of actors collectively aim for reconciling objectives of production with those of nature conservation and preservation of ecosystem services (Runhaar, 2017aa).

3.3. Selection of initiatives

We studied various initiatives in the Netherlands in dairy farming meadow landscapes where actors experiment with different ways of nature-inclusive landscape management. Initiatives were selected based on expert interviews and desktop research, according to the following criteria: (1) the initiative aimed to contribute to nature-inclusive agriculture; (2) the initiative was already in an implementation phase. We also sought for variety in the types of initiatives to enhance the robustness of our theoretical insights (Yin, 2009). For instance, we selected initiatives that emerged in various regions to identify the relevance and role of local factors in the organization of change. An overview of the initiatives is provided in Table 1.

3.4. Data collection and analysis

As change was initiated recently in the initiatives studied, limited documentation on the development of the initiative was available. Therefore, we conducted qualitative semi-structured interviews, which allow for the exploration of emerging phenomena. In total we conducted 22 in-depth interviews from October 2017 - June 2018 with representatives of the different organizations engaged in the initiatives. Next to this, we held additional interviews with experts in the sector to provide background information on the transformation of the dairy sector and the development of the initiatives. The interviews consisted of open-ended questions that revolved around theoretically-informed themes linked to the emergence of novelty: (1) the type of novelty introduced in the initiative; (2) the types of actors involved; (3) the activities and processes implemented in support of the development of the novelty; and (4) barriers to and conditions for change.

We recorded and transcribed all interviews, and prepared the interviews for analysis using NVivo coding software. We developed the initial codes in advance in accordance with the theoretically-informed themes described above: (1) type of novelty; (2) types of actors involved; (3) activities and processes implemented; (4) barriers to and conditions for change. First, we analyzed every initiative individually to gain an in-depth understanding of these topics on the level of the initiative, then we created four narratives. Second, to understand the cross-initiative patterns, we compared initiatives and proceeded to identify common themes. Third, we identified key distinctive characteristics and processes in dairy farming and compared them to previously studied ST transitions through various discussions between the researchers. We structured the main distinctive characteristics by: (1) type of novelty; (2) type of agency; (3) scaling potential. Studying the ecological impacts of the initiatives was beyond the scope of this research.

4. Results

4.1. Dynamics of change in the Dutch dairy sector

This section describes the emergence of novelty for the four initiatives aiming to promote biodiversity in the Dutch dairy sector (see Table 1 for an overview).

Table 1
Overview of initiatives for nature-inclusive landscape management in the Dutch dairy sector.

Initiative	Area in the netherlands	Novelty	Types of stakeholder and acronym (see Table 2 for the acronyms used)	number of interviews
A	Province of Friesland: Idzega	New business model for consumer product, based on price premium for sustainable landscape management	Sustainability consultant* (SC) Dairy cooperative, representative of the farmers guild* (DC) Supply chain actor* (Fi) NGO* (NGO) Retailers (Fi) Province of Friesland* (G)	5
B	Province of Noord-Holland: Amstelland	New business model for consumer product, based on price premium for sustainable landscape management; and model for land-lease under favorable conditions	NGO* (NGO) Regional coordinator of agricultural collective* (ANC) Foundation for land-lease* (Fo) Province of Noord-Holland* (G) Funding organization* (B)	5
C	National level	New measuring system for biodiversity, on which rewards can be based	Dairy cooperative* (DC) Bank * (B) NGO* (NGO) Research institute* (R)	4
D	Province of Utrecht: Vechtse Plassen	Access to land leased under sustainable conditions, and development of new sustainable business models	Foundation* (Fo) Land-managing nature organization* (LMO) Province of Utrecht* (G) Funding organization* (B)	4
	Context interviews (not project-specific)		National agricultural collective* Living lab focusing on nature-inclusive agriculture* Agricultural collective* (ANC) NGO* (NGO)	4

* = interview conducted.

Table 2
Acronyms used in the analysis.

Acronyms	Meaning
ANC	Agricultural nature collective
B	Bank
C	Consultant
DC	Dairy cooperative
Fi	Firm
Fo	Foundation
G	Governmental organization
NGO	Non-governmental organization
R	Research institute
LMO	Land-managing nature organization

4.1.1. Initiative A

This initiative started off with a few farmers in the province of Friesland who were in search of a way to create market value for efforts they already put into nature conservation on their farms. Different actors collaboratively developed a new business model in 2016 for a new brand for 'nature-inclusive milk' based on a price premium for the product; the consumer would pay € 002 extra per package for meadow bird conservation in the Frisian landscape. Nature-inclusive production in the landscape meant that natural areas on farmland were expanded and that farmers applied different management practices for agricultural nature conservation, such as the construction of puddle- and herb-rich grass areas for meadow birds and different mowing regimes with lower intensity to increase survival rates of meadow bird chicks (Interview DC1, 2017; Interview NGO1, 2017). In order to institutionalize this, guidelines for nature inclusive management were developed and recorded. When other farmers wanted to participate, they had to agree with these measures. According to one dairy cooperative: '*We have an agreement that the farmers expand meadow bird areas from 10 to* 20 %' (Interview DC1, 2017).

Business model development posed several challenges. First, a way had to be found within the dairy cooperative to distinguish the milk according to nature-inclusive practices from farmers in the dairy cooperative who produced dairy in a regular way. However, the dairy cooperative resisted to distinguish between farmers in favor of some farmers receiving a price premium. According to a consultant involved: "*I thought it would fail. At the level of the cooperative there is a 100-year-old 'law' that every farmer gets paid the same within the cooperation*" (Interview C, 2017). The consultant in this initiative played a key role in lobbying for a separate milk stream for these farmers. A new cooperative was found to be willing to organize a separate milk stream, through which these could be

rewarded with a price premium. The participating farmers had to be united in a new collaborative structure to distinguish themselves within the cooperative: *a Farmers' Guild*.

A challenge in this initiative was to get commitment from retailers, since these were focused on cost-reduction. *"We didn't pull the market development off in the beginning. We came a long way with a Dutch supermarket at first; this supermarket was interested in converting its private milk label into our nature-inclusive milk stream. It would have been about 30 million liters, produced by 50 farmers. Eventually the deal was not closed because of a price gap of a few cents per liter"* (Interview C, 2017). In the end, they got the opportunity from a retailer to develop their own brand (Interview Fi1, 2018). Several actors played an important role in the organization of the business model. The dairy cooperative, the Farmers Guild, the processing firm in the supply chain (which was the direct link to the retailer) and a bird conservation NGO developed the proposition. The processing firm in the supply chain organized the production process and provided the resources for it. Lastly, an NGO was involved to help create legitimacy in the consumer market by confirming the sustainability aspect of the story. According to the processing firm: *"We were searching for an independent actor to link their name to our story. The NGO played a role in the requirements and safeguarding of the sustainability side of the story. That was an important actor for us. We can believe in our concept, but it is important that this NGO backs it up"* (Interview Fi1, 2018).

The development of a story behind the milk product was mentioned to be key for marketing, especially since milk was not considered to be a distinguishable product. "*We started many demos to tell the story to consumers…not to let them taste the milk per se; it's not such a sexy product where people would come for, but it gave us the opportunity to show what we stand for, what the farmers do, actually the whole story. Then you hope that people are charmed, like the product, and will buy it"* (Interview Fi1, 2018). The fact that the farmers were known by the consumers of Frisian supermarkets was mentioned as an important success factor since they live in the same region.

Several upscaling challenges were mentioned. It was a challenge to sell the milk with a price premium since consumer demand was limited. The processing firm mentioned that they had to sell the nature-inclusive produced milk as part of their other brands without a price premium (Interview Fi1, 2018). This upscaling barrier limited the engagement of more farmers in the landscape. Respondents mentioned that a specific standard for nature-inclusive production, similar to organic products, would contribute to upscaling. Currently, a new standard is being developed to secure a stream of sustainable dairy products in the Netherlands, which might help create legitimacy and market demand for those products.

4.1.2. Initiative B

In this initiative in the province of Noord-Holland, started in 2015, the regional coordinator of an agricultural collective and an NGO for bird conservation aimed to create core areas for meadow birds, and adapt farming practices in the landscape accordingly with buffer zones and more sustainable management practices (Interview NGO2, 2018; Interview ANC1, 2018; interview Fo1, 2018). The goal was to engage as many farmers in nature-inclusive practices as possible in order to enable conservation on a landscape scale (Interview NGO2, 2018; Interview ANC1, 2018). Different practices comprised higher groundwater levels, late mowing to ensure chick survival of meadow birds, applying rough manure and growing herb-rich grasses. Moreover, expanding natural areas in the landscape was important. According to the regional coordinator: *"My goal is to create 20–30% of nature in a polder, on the right locations"* (Interview ANC1, 2018). Current subsidies to stimulate meadow bird conservation were perceived as an important driver for measures already taken in this region, but also as uncertain and unstable (Interview ANC1, 2018; Interview G1, 2018). Therefore, new business models are developed in the region to stimulate farmers to participate in nature-inclusive practices. In this initiative, a new model was developed for farmers to lease land under favorable conditions. Land would only be leased to farmers when they complied with certain nature-inclusive conditions (interview Fo1, 2018). In turn, land could be leased at a relatively low price. For this reason, a new foundation was developed that acted as a new entrant in the market for buying land. With help from a private investor found by the NGO, 16 ha of land was acquired and rented to the foundation under a contract with low interest rates and for a long period of time (30 years). Cultural barriers were perceived for this actor to buy land, as the land was already owned by farmers for several generations and the foundation was seen as a competitor (interview Fo1, 2018).

The second development in this initiative was a regional business model with a price premium on milk for farmers that complied with biodiversity friendly practices. Moreover, a few cents per liter of milk would be invested back in the landscape for extra conservation measures. To realize this new regional business model, a new cooperative of farmers was established together with a new milk factory. The reason to open a new milk factory instead of using an existing one was motivated by the desire to keep the milk authentic to ensure the regional character, instead of being mixed or standardized in other existing milk factories (Interview NGO2, 2018; Interview ANC1, 2018).

A major challenge was that farmers often already had contracts with dairy cooperatives, and could not just supply their milk to the new cooperation they started. The NGO and the regional coordinator played a key role to lobby with the cooperative of which the farmers were members, and came to the agreement that farmers could use 30 % of their milk toward the new business model. About 20 of the 50 farmers in the area were interested in joining as members of the new cooperative (Interview NGO2, 2018; Interview ANC1, 2018). The NGO and regional coordinator played an important role in attracting funding for the new milk factory, which was perceived as a challenge, since banks were resisting to invest. Funding came from various parties, such as foundations, the province, municipalities and from farmers themselves (Interview ANC1, 2018; Interview G1; Interview Fo2, 2018).

The regional character of the business model could provide an attractive marketing story, and the connection between farmers and citizens in Amsterdam was said to have a positive effect on demand. Raising the interest of these citizens in the landscape was considered important for preserving it. As one interviewee mentioned: "*Key for a sustainable region is to make sure that the citizens from Amsterdam get to know the countryside and learn to appreciate it, and in turn will be prepared to fight for its preservation"* (Interview Fo1, 2018). In the search of potential buyers for the new milk brand, the NGO linked the farmers with local businesses in Amsterdam: "*We*

literally brought the farmers in two vans to the city and organized a few meetings to let them talk with potential clients such as the coffee company and some restaurants. Wholesalers in Amsterdam tasted the milk, and we showed them that there is supply but that they have to go to the farmers and buy it" (Interview NGO2, 2018). Respondents in this initiative mentioned that these types of small initiatives could set a trend in the market. Moreover, the NGO involved was working on the development of a new standard to help institutionalize conditions for nature and environmental conservation in the Dutch agricultural sector.

4.1.3. Initiative C

The goal of this initiative was to increase biodiversity in the Dutch dairy sector. A collaboration between three parties was set up in 2013: the largest dairy cooperative in the Netherlands, a bank and a nature conservation NGO. The partnership was said to be a strategic decision by which their leverage and legitimacy could stimulate a large group of farmers: *"With these parties we already have a huge coverage of the dairy sector. The cooperative is owned by* 16,000 *of the* 18,000 *farmers in the Netherlands* (Interview NGO3, 2017).

In this initiative, a systemic instrument was developed to reward farmers based on biodiversity efforts. More specifically, a biodiversity monitor with key performance indicators was developed to assess progress towards determined ecological targets. Key performance indicators (KPIs) were identified for four pillars of biodiversity: (1) functional agrobiodiversity (e.g. fertile soils and closing nutrient cycles on farms); (2) diversity of landscape (e.g. landscape elements such as trees, ditches and hedges); (3) diversity of species (e.g. targeted improvement of habitat management for specific species); and (4) regional biodiversity (e.g. connecting areas between farms and regional management). The KPIs were considered to be related and were proposed as an integrated set to assess biodiversity performance (Interview NGO3, 2017; Interview RI1, 2017).

Identifying the right criteria to guide biodiversity goals was considered essential: *"You have to be sure. When we go in a certain direction based on specific criteria, and those criteria are not tested or scientifically proven, there is the danger of steering farmers into wrong directions, and that could even have a negative effect on the profitability in the end"* (Interview B1, 2017). Research institutes played an important role in identifying KPIs and analyzing trade-offs between biodiversity indicators (Interview RI1, 2017). However, the national focus of this initiative to engage large groups of farmers appeared to be a challenge in terms of developing the instrument, since the regional context and conditions determine the type of measures needed. For instance, peat meadows require different management in comparison to sandy soils. A regional approach was thus needed for the development of the indicators. Collaborations were established with regional actor networks, as these could provide specific regional knowledge on desired values for basic ecological quality, and to define regional goals. Regional farmer study groups were approached to gain more knowledge on certain topics. Pilots were initiated to test the instrument in six areas in the Netherlands together with the agricultural nature collectives (Interview NGO3, 2017; Interview DC2, 2018).

Rewarding instruments based on biodiversity performance were different for the different actors involved, depending on the leverage they had. For the bank, higher sustainability scores on biodiversity would result in loan discounts (Interview B1, 2017). The dairy cooperative provided a price premium to the farmers. For the cooperative, it was important to create legitimacy for this instrument in order to get it adopted by the members of the cooperative, the farmers themselves. Communicating and engaging with farmers were important to create legitimacy. According to the dairy cooperative: *"It is a whole process of awareness creation and it takes time. You need more than an incentive, you also need to tell a story, and tell what grows on their farms, and why that is beautiful. It's not only about financial rewards, there is a societal reward as well"* (Interview DC2, 2018).

In this initiative, stakeholders actively tried to create legitimacy by lobbying for this instrument to be more widely adopted and implemented (for instance, by its integration into the European subsidy system). Interaction with ministries, provinces, agricultural collectives and nature associations often took place, and feedback from other parties was perceived as important, since this increased legitimacy and reliability of the instrument for other actors to use it (Interview NGO3, 2017; Interview DC2, 2018). According to the NGO: "*We find it important that other actors use this instrument as well. For instance, when a farmer produces in balance with nature, his or her dairy cooperative could provide a reward, but also the landlord from whom they rent land can provide rewards, and the water authorities as well, by lowering taxes for water use for instance; in this way rewards could be added up for farmers.*" (interview NGO3, 2017). Respondents mentioned that other parties often approached them due to their legitimacy. *"Our combination [of actors] is very strong. We are large parties with a clear vision, on a theme surrounded by a lot of uncertainty."* (Interview B1, 2017). Respondents mentioned that it will be important to develop a label based on this monitor to assure that criteria are safeguarded in a framework when other actors use it, and would thus not only 'cherry-pick' criteria that they like to use.

4.1.4. Initiative D

In this initiative, a land-managing nature organization and a foundation specialized in the development of sustainable business cases for landscape restoration aimed to stimulate farmers in a region in the province of Utrecht (the Vechtseplassen) to switch to nature-inclusive management practices. Different models have been developed since 2015. The Province was involved in subsidizing the pilot (Interview G2, 2018).

A key model developed in this initiative was a new lease contract for farmers, in which 'nature-inclusive' conditions for land leases were developed (Interview LMO, 2018; Interview Fo3, 2018). The land-managing nature organization already leased their natural grasslands to farmers under biodiversity-friendly management conditions. However, for these farmers, this was often only a small share of their total farmland, which could be located elsewhere and could be intensively managed. Until then, the nature organization did not influence the management of farmers outside of their own natural grasslands. In this initiative, the nature organization aimed to expand their leverage by developing a new model in which they would only collaborate with farmers who would farm by means of nature-inclusive practices on the total amount of their farmland. *"I currently have a tenant, and I am very happy with his management on our natural areas…. He does it at the right time and in the right way. However, this farmer manages his own land very intensively; it looks like*

one green billiard cloth. Landscape elements, such as hedges and trees are slowly disappearing. According to our new strategy we have to say 'even though this farmer manages our land very well, we will not collaborate with him/her anymore'. This is the movement we are starting: we are going to make choices with whom we work to influence landscape management on a larger scale" (Interview LMO, 2018). This new approach implies that the nature organization had to let go of a number of farmers, and developed tighter collaborations with less farmers. The impact of this proposed measure was first discussed with individual tenants. *"We don't want people to get in trouble due to a change in management measures – we first needed to talk with all farmers about it"* (Interview LMO, 2018). Reasons for participation were that farmers understood that a change was needed in the region and that they had to engage in the initiative if they wanted to stay part of the landscape. Leasing land under nature-inclusive conditions to farmers for a favorable price was discussed as an important solution to stimulate farmers to switch to nature-inclusive agriculture. Importantly, the foundation involved in this project was also working with a sustainable financing foundation to develop new lease constructions (Interview Fo2, 2018; Interview Fo3, 2018).

Experimentation with new business models based on nature-inclusive management practices was also part of this initiative to make it financially more attractive for farmers to engage in nature-inclusive agriculture. The foundation played an important role in identifying themes for business models out of conversation rounds with individual farmers. Experimentation related to potential business cases revolved around regional supply chains, and the development of products derived from grass mown in the natural grassland areas, which could deliver financial benefits (Interview Fo3, 2018). Pilots and experimentation with practices with different ecological benefits, such as improving soil biodiversity, and the financial aspects of the business cases, were key in this initiative to further develop and diffuse knowledge, create legitimacy and engage more farmers in the landscape. Stakeholders focused on quick action: "*Some people find it too fast, because we do not know at all if it works. But if we have to wait another five years before we know if it works … we're just going to try it on a small scale now, because we want to put that engine in motion."* One of the ideas was a tailor-made nature-inclusive 'menu-card' with different measures that farmers could take depending on what would suit them best on their farm (Interview Fo3, 2018). In both models, there was a strong focus on bottom-up organization, with the farmers as key actor for change. "*The core group of actors needed to implement changes in the landscape are landowners, e.g. the terrain owning organizations, or farmers. And next to this you need entrepreneurs to develop sustainable business cases."* (Interview Fo3, 2018). A precondition for developing new models was investing in the landscape network. *"We already see how much we have to invest in building a network with farmers before there is traction and things actually start to happen."* (Interview Fo3, 2018). The foundation worked with a so-called *'landscape mobilizer'*; i.e. a person who specifically works on maintaining a network with farmers. The foundation played an important role in building trust between farmers and the nature organization. This was essential since agricultural and nature organizations often have tensions due to opposing views on landscape use (Interview Fo3, 2018; Interview G2, 2018).

5. Analysis and discussion

5.1. Transition dynamics in a sustainability transition in the Dutch dairy sector

In this section, we build on our empirical description and elaborate on common patterns and dynamics of change found in the studied cases. In each subsection below, we first provide an analysis of our findings and subsequently provide theoretical reflections for the field of transition studies, by discussing how our findings relate to the transition literature and to earlier identified socio-technical transition dynamics. Lastly, we discuss implications for upscaling and expected scaling dilemmas. Table 3 summarizes the main findings derived from our cases and implications for upscaling.

Table 3
Summary of findings: case insights and implications for upscaling.

	Case insights
Agency	• Farmers are regime actors, and not new entrants at the niche level. Farmers are key actors who can implement landscape change (biodiversity-friendly practices), but they are also deeply embedded in the current agro-regime. Incentivizing change from regime actors was important to stimulate and enable change. Other actors, such as NGOs or supply chain actors, play a key role in developing incentive systems.
Novelty	• Institutional change consisted of new socio-institutional frameworks and incentives for farmers to change agricultural practices, often in the form of business models. Learning was not focused on cost reduction, but on the development of biodiversity-friendly practices and on creating value for biodiversity in new business models. Different approaches were needed in different regions due to specific ecological challenges and solutions, different networks of local actors and collaborations and specific institutional settings.
Implications for upscaling	• The importance of geographic embeddedness addresses the need for a fit between novelty and place due specific local social-ecological conditions. Models for change cannot easily be scaled, replicated or standardized. There is no 'one size fits all', implying that in every region, new approaches need to be developed with new stakeholders, new experiments and new institutions. • Since incentives come from exogenous sources of novelty, it is unlikely that scaling this novelty from the micro to the meso-level will come from farmers themselves. • Even when biodiversity-friendly niche practices break through to the regime in the agricultural sector, it is unlikely that they will ever be competitive at scale without continued incentives.

5.2. Dynamics of agency and novelty

5.2.1. Case findings

In terms of actual landscape changes, different types of management and organization of landscapes were key.

The mission of the initiatives was to enhance biodiversity in the landscape. In all cases, respondents mentioned that farmer participation is crucial. Farmers are the only actors who can implement direct agricultural landscape changes by adapting management practices, such as by growing different grass species, late mowing to increase survival of meadow bird chicks, raising water levels and by expanding natural areas as habitat for meadow birds. Dairy farmers are deeply embedded in the current agro-regime. In the cases we studied, some farmers were however engaged in novel practices, which we classify as niche activities. However, they often did not initiate change, since most farmers face large challenges to conserve biodiversity. Biodiversity-friendly practices in our cases implied additional costs, and also often decreased the productive area for dairy production. Moreover, in some cases farmers faced resistance from actors in the supply chain. Creating market demand for biodiversity-friendly products was challenging, and resources to initiate change were often lacking. Therefore, enabling and stimulating farmers via incentives to break out of the regime and experiment with novel practices were perceived as important in our cases.

These incentives often came from external sources of novelty. Actors such as NGOs catalyzed change processes in various ways. They enabled farmers to overcome regime barriers, for instance by helping them to break free from current supply chain structures and contracts before they could engage in new ways of management, or by facilitating the mobilization of resources. The investment in local relationships and networks and building trust were essential to gain legitimacy. Having a network in the landscape and trust from and amongst farmers contributed to the engagement of farmers, which was for instance achieved through focusing on bottom-up change and building personal relationships. Existing collaborative structures and networks in the landscape, such as agricultural nature associations and collectives, contributed to connecting and engaging farmers.

The main novelties were based on financial incentives for farmers to shift to biodiversity-friendly management practices, such as business models with price premiums, and beneficial land lease contracts under nature-inclusive conditions. In two cases, the business model revolved around the development of a product – nature-inclusive milk. This required a different organization of supply chains and creating market access and demand for the new product. Market demand was especially challenging since the product was sold at a higher price, while it had the fairly similar physical characteristics as other milk products. Creation of legitimacy therefore seemed key in these forms of business models. In our case this was created through (1) involvement of NGOs, (2) emphasis on the story behind the product and (3) connecting citizens and the landscape through regional business models. Stakeholders hoped that regional products would enhance consumer involvement, since consumers from the same region would more likely pay a price premium for biodiversity-friendly practices in their “backyard”. These incentive systems were institutionalized by new frameworks, collaborative agreements and labels, such as frameworks for nature-inclusive management and the development of a systemic instrument to steer on biodiversity conservation, or by establishing new cooperative structures (for instance the development of a Farmers’ Guild).

5.2.2. Theoretical implications for transition studies

Our case observations highlight some important differences with previously studied transition dynamics. Many transition studies highlight the importance of entrepreneurs who develop and diffuse novelty. They are often labelled as new entrants, external to the regime, who try to enter existing regimes with new technology (Geels et al., 2016). The rise of novel technologies often leads to large shifts in industrial leadership (Utterback, 1994; Geels et al., 2016). In our case, the actor constellation was rather fixed, as geographical embeddedness determines, to a great extent, which actors are able to engage in change. New management practices hence need to be adopted by existing farmers. Farmers who contributed to the transition can be classified as regime actors instead of new entrants at the niche level. Even though more recent MLP theorization acknowledges the important role of regime actors in transitions, the transition literature dominantly focuses on large and powerful regime actors with the capital and resources to pursue change (Kishna et al., 2017). The agricultural sector however is characterized by a significant number of regime actors with limited size and resources, and skewed power divisions exist between farmers and other actors in the supply chain. This limits the ability to single-handedly change practices (PBL, 2018; Runhaar, 2017a; Kishna et al., 2017). Additionally, financial incentives were important in the case of biodiversity conservation to motivate actors to engage. This resulted in transition dynamics which revolve around enabling and incentivizing regime actors to partake in transition processes. Thus far, the transition literature has paid limited attention to these type of transition dynamics.

The need for incentive systems to conserve nature are well understood in the literature on biodiversity conservation and social-ecological systems. This literature focuses extensively on the need for new institutional arrangements to motivate actors to invest in biodiversity, such as incentives and rules to stimulate actors to invest in sustainable management, and institutional frameworks that set conditions for these incentives or rules (Gardner et al., 1990; Ostrom, 2009; Pascual and Perrings, 2007; Batáry et al., 2015; Guerrero and Wilson, 2017). We have shown that NGOs are important agents of this type of institutional change, and that they play decisive roles in change processes by developing institutional novelty and creating favorable institutional conditions. Our findings are therefore in line with previous studies that focus on institutional arrangements and labels to incentivize more sustainable production of natural resources and crops, such as the FSC and Fair trade labels (Klooster, 2005; Bartley, 2007).

5.3. Place-based embeddedness and implications for upscaling

5.3.1. Case findings

Each region has different ecological challenges and solutions, different networks of local actors and collaborations present, and specific local institutional settings. Our cases show that different approaches were needed in different regions, and that solutions were thus anchored in landscapes. The type of participation was guided by ecological conditions. For instance, a buffer area placed around a core area for meadow birds required the specific engagement of farmers located in those buffer areas. Moreover, local knowledge on the presence of meadow birds and region-specific soil and water conditions were perceived as important, in addition to collaborations with local actors, e.g. agricultural nature collectives, to develop regional goals for biodiversity-friendly management. Since collective efforts are needed on a landscape scale to achieve positive biodiversity effects, collaborations between farmers are required, which are specific for different landscapes (Tscharnke et al., 2015), but also depend strongly on the willingness of local actors to engage. This place-based character implies that successful models for change cannot easily be scaled, replicated or standardized. There is no 'one size fits all', implying that in every region, new approaches need to be developed with new stakeholders, new experiments and new institutions.

5.3.2. Theoretical implications for transition studies

Considering the large variety in social-ecological conditions in various contexts, upscaling mechanisms, such as policies that promote the adoption of sustainable agricultural technologies or practices, should be based on a match between novelty and local social-ecological conditions. This requires paying specific attention to relevant social-ecological elements, which are well described in neighboring fields of SES. Since farmers are spatially confined, they will not be able to scale up individually. The agri-food transition requires millions of individual farmers to change their practices. At the same time, adapting to local circumstances is key for farmers. The geographic embeddedness of actors therefore increases complexity in this transition, and probably results in distinct and slower scaling dynamics in comparison to other domains. In terms of upscaling, this could imply that the main concept of an experiment can be used in a different location, but needs to be complemented with context-specific local knowledge (Naber et al., 2017). In terms of regime rules, these will most probably need to be regionally addressed since they are strongly linked to place-based factors, known as "spatially sticky" innovation dynamics (Binz and Truffer, 2017). This is in stark contrast with socio-technical transitions that depend on technologies that are developed through a science and technology rationale, can be standardized and are less dependent on local valuation. Future work in the field of transition studies could focus more explicitly on the regional character of regimes.

5.4. The public goods' character of biodiversity and implications for upscaling

5.4.1. Case findings

Our cases indicated that farmers incentives for biodiversity conservation are key. Biodiversity-friendly practices were often not directly economically beneficial to farmers, and moreover in our case lowered the productive area for grass production and incurred higher costs. Biodiversity-friendly milk products are moreover structurally more expensive than regime products.

5.4.2. Theoretical implications for transition studies

This is rather different from dominant upscaling patterns described in previously studied domains, where diffusion mechanisms are often driven by technological learning in the niche, leading to lower prices. Previous studies in the energy domain have shown that learning mechanisms resulted in cost reductions and improved price/performance ratios, which in turn increased market diffusion (wind power (Anzanello and Fogliatto, 2011); solar PV, wind, biogas in Germany (Sovacool and Geels, 2016). It is thus often assumed that, after initial protection through strategic niche management, technologies will be able to survive in the regime without such protection (Junginger et al., 2006). In our case, additional learning may lead to enhanced biodiversity conservation, but most probably not to lower production costs. Therefore, different scaling dynamics are expected. Even when niches become successful, it is unlikely that these niches break through as long as regime conditions do not change (Smith and Raven, 2012). A broader regime transformation (e.g. involving market and institutional changes) is needed to incentivize biodiversity conservation, as to overcome tendencies to underinvest in biodiversity. Our cases demonstrate that actors were aiming to change broader regime conditions and create a level playing field by lobbying for the use of frameworks that promote biodiversity by other actors and by advocating for different regime rules. Either structural funds are made available to compensate farmers for higher costs, new rules need to be implemented to increase the price of existing non-sustainable agricultural products to account for negative externalities (true pricing) or minimum environmental standards should be set for all agricultural products. Moreover, feasible business models were perceived as a powerful way to create legitimacy for broader change and to attract incumbent actors.

6. Conclusion

As the global loss of biodiversity is one of the most pressing environmental concerns, a sustainability transition towards conservation of nature that halts the rapid decline of biodiversity is urgently needed. Transforming the agri-food sector towards a more sustainable sector in which biodiversity is enhanced is required, but has received very little attention in the sustainability transitions literature.

In this paper, we provide insights into how transition dynamics unfold in a sustainability transition in the Dutch dairy sector by applying a socio-technical perspective. The role of ecology is salient in the agri-food sector, and we illustrate how ecological

dimensions affect dynamics of change in this sustainability transition. We studied agricultural practices to promote biodiversity as an innovation. The MLP framework provides a strong lens for explaining sectoral change and lock-in and understanding dynamics between conceptual levels of niches and regimes. On the surface, many transition processes found in our case are similar to previously studied socio-technical transitions, such as the strong lock-in of the dairy sector, where regime rules are hard to change, and a poor fit of novel practices in current regime environments (e.g. the resistance to separate milk streams, locked-in relationships between farmers and cooperatives and low prices of regime products). However, we claim that sustainability transitions in the agri-food sector to enhance biodiversity deviate from other sustainability transitions (e.g. socio-technical transition dynamics in the mobility and energy sector) due to the central role of ecology. Two key characteristics, i.e. the place-based dependencies of agricultural systems and the public goods' character of biodiversity, shaped dynamics of change in the agricultural sector in various ways:

1 Due to the place-based embeddedness, change is dependent on the engagement of a significant number of landowners who are part of existing regimes. These regime actors often need to be enabled and incentivized to partake in the transition process. These incentives come from exogenous sources of novelty. In our case, NGOs play a prominent role in developing incentive systems.
2 Including biodiversity and the protection of nature shapes transition dynamics in the sense that there is a strong focus on the development of incentive mechanisms due to the public goods' character of biodiversity. Even when biodiversity-friendly niche practices break through to the regime in the agricultural sector, it is unlikely that they will be competitive at scale without continued incentives. Innovation in our case is thus less likely to lead to reduced costs compared to previous studies on the energy and mobility domain. Therefore, there is a high dependence on processes of institutional change that create financial incentives. The search process for new business models that, on the one hand lead to nature conservation and on the other hand, lead to income for landowners is key in this transition process.
3 Agricultural landscapes show large geographical, biophysical and ecological variation. The place-based character of novel agricultural practices implies that these practices cannot be scaled across different geographical regions without adaptations to local ecological circumstances. The spatially sticky character of solutions depend on the environmental conditions, thus there is a need for a specific fit between social-ecological conditions and innovation. This not only holds for novel agricultural practices, but also for the institutional conditions that incentivize these novel practices. The place-based character of both practices and institutions is likely to lead to complex scaling dynamics, perhaps more than in energy and mobility sustainability transitions that have been frequently studied.

This study could also contribute to neighboring fields studying sustainable transformations in the context of ecosystem conservation (e.g. social-ecological systems, transformative adaptation and sustainable pathways (Olsson et al., 2014; Moore et al., 2014; Westley et al., 2011; Patterson et al., 2017)). Studying these transformations from different scientific lenses is valuable as it can provide an integrated understanding of different parts of the puzzle. A socio-technical lens could serve valuable purposes for other fields, since it provides a deeper understanding of transition dynamics and the sectoral lock-in of agri-food regimes related to biodiversity conservation. From a transition perspective, turning to the neighboring fields of SES and biodiversity conservation to unpack relevant implications of biodiversity conservation was useful to substantiate the forms of transition dynamics found. A closer interaction between sustainability transition scholars and the community that studies social-ecological systems would be highly beneficial.

Our conclusions are based on sustainable dairy production in The Netherlands. More case studies are needed to generalize dynamics of change. Further research could focus on agricultural sectors in different geographical areas (such as the Global South) and different types of agricultural production systems and related business models such as agroforestry systems, in which different financial or ecological benefits could be achieved. Moreover, further research could focus on different transition models to study sustainability transitions in the agricultural sector, as well as the role of ecology in these transition models.

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Interview DC2, interview conducted in person on 3-5-2018.
Interview Fi1, interview conducted by phone on 30-5-2018.
Interview Fo1, interview conducted in person on 25-5-2018.
Interview Fo2, interview conducted on 30-4-2018.
Interview Fo3, interview conducted on 10-4-2018.
Interview G1 [interview conducted in person on 4-5-2018.
Interview G2, interview conducted in person on 8-5-2018.
Interview LMO, interview conducted in person on 9-5-2018.
Interview NGO1, interview conducted in person on 22-10-2017.
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